

HYDROELECTRIC PLANT  
ON MISSISSIPPI RIVER, MOLINE, ILLINOIS

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

1914

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Design of hydroelectric  
plant on Mississippi River,

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DESIGN OF HYDROELECTRIC PLANT

-on-

MISSISSIPPI RIVER, MOLINE, ILLINOIS.

A Thesis Presented by:

Arthur G. Heeren  
J. C. Keely  
Wm. Oldenburger.

To

The President and Faculty

of

Armour Institute of Technology

For the Degree of

Bachelor of Science in Civil Engineering

Having completed the Prescribed Course in

Civil Engineering.

Chicago, Illinois.

May 1914.

Alfred Phillips Prof. of Civil Eng.

E. V. Freeman Prof. of Elect. Eng.

John P. ...

L. C. Morin

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## INTRODUCTION.

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In presenting this thesis for approval by the Faculty of the Civil and Electrical Engineering Department of the Armour Institute of Technology, it has been the aim of the students to carry out as nearly as possible, present practice in the design of hydro-electric power stations.

Standard practice has been closely adhered to wherever possible, no attempt being made at original design in such things as machine parts and electrical equipment. All other designs, however, have been made according to the students' best knowledge.

It is not the intention of the students to present a complete and detailed design of the installation, but merely such a design as would prove of great use in promoting such a development and showing the feasibility of the project.



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1. The first part of the document discusses the importance of maintaining accurate records of all transactions and the role of the accounting department in ensuring the integrity of the financial statements.

2. It also highlights the need for transparency and accountability in the financial reporting process, emphasizing the importance of disclosing all relevant information to the stakeholders.

3. The second part of the document focuses on the implementation of internal controls and the role of the internal audit function in monitoring and evaluating the effectiveness of these controls.

4. It also discusses the importance of regular communication and collaboration between the accounting department and other departments to ensure the accuracy and completeness of the financial data.

5. The third part of the document addresses the challenges faced by the accounting department in the current business environment, such as the increasing complexity of financial transactions and the need for advanced technology solutions.

6. It also provides recommendations for overcoming these challenges, including the implementation of robust internal controls, the use of automation, and the hiring of skilled professionals.

7. The fourth part of the document discusses the importance of staying up-to-date with the latest accounting standards and regulations, and the role of professional organizations in providing ongoing education and support.

8. It also emphasizes the importance of maintaining a strong ethical foundation and the role of the accounting department in promoting transparency and accountability in the financial reporting process.

9. The fifth part of the document discusses the importance of maintaining accurate records of all transactions and the role of the accounting department in ensuring the integrity of the financial statements.

10. It also highlights the need for transparency and accountability in the financial reporting process, emphasizing the importance of disclosing all relevant information to the stakeholders.

## LIST OF DRAWINGS.

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## THE GENERAL PROBLEM.

In general the developement will consist of a dam across the river which may also be made to act as a spillway by raising vertical gates, a shore dam or retaining section, a power house and ship locks. The problem which presents itself is to determine the amount of power which can be economically developed. To do this, we must resort to government data, whereby we may determine the maximum and minimum stream flow and the available head and base our calculations accordingly.

The ship locks must be made according to government specifications, and as time does not permit we will not attempt to do anything with this branch of the project.

## LOCATION OF SITE.

The proposed development is situated on the Mississippi River about seven miles north of Rock Island, Illinois, and six miles north of Davenport, Iowa, the distances being measured along the river. Part of the electric power developed is intended to be used for manufactur-





ing purposes in these towns and part is to be transmitted by high voltage to neighboring towns.

The advantages for construction and other purposes are excellent. The C.R.I. & P. R.R. and the C.M. & ST. P. R.R. run within a short distance of the site, and the C.R.I. & N.W. R.R. runs along the river bank. These railroads afford convenient means of communication with Moline and Rock Island and present ample means for transportation purposes. The river itself also presents excellent and cheap means for transporting construction materials.

#### SOURCE OF POWER AND STREAM MEASUREMENTS.

The source of power for this development lies in the fall of the river between Le Claire, Iowa, which is at the head of the rapids, and Rock Island Bridge at the foot of the rapids. From the head of the rapids to the site of the proposed dam the low water fall is 10.77 feet and the high water fall 8.67 feet. The low water elevation was assumed to be raised to Elev.



576.144 by building the dam thus giving a head of sixteen feet.

The period of lowest flow which occurred in 1864 shows that the discharge of the river at this point was 17,000 cubic feet per second, and the maximum discharge recorded is 250,000. second feet.

Government readings of the daily gage height at Rock Island, Illinois, for forty years are available, from which the stream flow could be calculated for every day. These gage readings, however, are too costly for our purpose, and it was decided to obtain only the readings for the lowest water year which are given on pages

A profile of the river at Rock Island was not available, so a cross-section of the river further up, giving approximately the same area and wetted perimeter, was used. Assuming that the velocity and discharge in this section were the same as those at Rock Island for minimum and maximum discharges, the water surface was given the same gage reading as those taken at Rock Is-



land. Other values for discharge were calculated by interpolation. From the above data we were able to plot a rating curve for the river at Rock Island where the zero of the gage reading, i.e. the lowest flow, corresponded to a discharge of 20,000 cubic feet per second. By changing the horizontal scale so as to read 17,000. instead of 20,000 the rating curve at the proposed site was obtained.

With the aid of the rating curve and the gage reading shown on pages 7-9 we were able to plot a hydrograph for the lowest water year at Rock Island. Then changing the vertical scales so as to read 17,000 instead of 20,000, a hydrograph of the river at the proposed site was obtained.

#### BACK WATER CALCULATIONS.

Assuming the river to be at the low water stage, the calculations for "C" in the formula:

$$C = \left( \frac{L}{Rh^{3/2}} \right)$$

were made in which the letters have the meaning as given below:



C = Coefficient depending on roughness of the channel.

V = Velocity at the section considered.

L = Length in feet between two sections.

h = Difference in elevation between two sections.

With 17,000 cubic feet flowing in the river, the coefficient "C" was determined for sixteen sections of the river. The average value of "C" thus determined was 50.

With the dam constructed and the elevation of the water surface raised to elevation 576.34 feet, the height of the water surface at Le Claire was determined, the discharge being taken as 250,000 cubic feet per second. The elevation of the water surface at Le Claire was found to be 587.098 feet.

Le Claire would not be affected by the building of the dam, but Rapids City across the river would be flooded to a height of 3.198 feet above the high water mark. This matter could be taken care of by either building a small retaining wall or by compensating the riparian owners who sustain any damages.





GAGE READINGS AT ROCK ISLAND BRIDGE 1891.												
DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1.	1.0	1.0	3.4	6.9	10.1	3.15	3.0	1.3	0.5	0.05	1.0	1.6
2.	0.9	1.45	3.4	7.35	10.2	3.1	2.95	1.2	0.55	0.00	0.95	1.4
3.	1.5	2.3	3.3	7.6	10.3	3.0	2.9	1.2	0.6	0.05	0.85	0.7
4.	1.5	3.9	3.6	7.65	10.3	3.1	3.1	1.15	0.55	0.2	0.8	0.3
5.	1.35	5.6	3.3	7.65	10.3	3.15	3.2	1.2	0.5	0.2	0.8	0.1
6.	1.2	6.1	3.1	7.65	10.2	3.4	2.95	1.2	0.5	0.25	0.8	0.3
7.	1.1	5.55	2.8	7.75	10.0	3.4	3.1	1.1	0.45	0.35	0.7	0.25
8.	1.2	5.45	2.9	7.85	9.7	3.2	3.25	1.0	0.45	0.45	0.8	1.7
9.	1.3	4.9	2.6	7.9	9.5	3.1	3.4	1.0	0.4	0.6	0.85	2.3
10.	1.4	5.5	2.3	8.1	9.05	3.0	3.4	0.9	0.4	0.7	0.9	1.9
11.	1.2	7.0	2.1	8.35	8.7	2.85	3.2	0.9	9.35	0.75	0.9	1.65

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132
133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204
205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228
229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272	273	274	275	276
277	278	279	280	281	282	283	284	285	286	287	288
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301	302	303	304	305	306	307	308	309	310	311	312
313	314	315	316	317	318	319	320	321	322	323	324
325	326	327	328	329	330	331	332	333	334	335	336
337	338	339	340	341	342	343	344	345	346	347	348
349	350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371	372
373	374	375	376	377	378	379	380	381	382	383	384
385	386	387	388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405	406	407	408
409	410	411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440	441	442	443	444
445	446	447	448	449	450	451	452	453	454	455	456
457	458	459	460	461	462	463	464	465	466	467	468
469	470	471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490	491	492
493	494	495	496	497	498	499	500	501	502	503	504
505	506	507	508	509	510	511	512	513	514	515	516
517	518	519	520	521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550	551	552
553	554	555	556	557	558	559	560	561	562	563	564
565	566	567	568	569	570	571	572	573	574	575	576
577	578	579	580	581	582	583	584	585	586	587	588
589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612
613	614	615	616	617	618	619	620	621	622	623	624
625	626	627	628	629	630	631	632	633	634	635	636
637	638	639	640	641	642	643	644	645	646	647	648
649	650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671	672
673	674	675	676	677	678	679	680	681	682	683	684
685	686	687	688	689	690	691	692	693	694	695	696
697	698	699	700	701	702	703	704	705	706	707	708
709	710	711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730	731	732
733	734	735	736	737	738	739	740	741	742	743	744
745	746	747	748	749	750	751	752	753	754	755	756
757	758	759	760	761	762	763	764	765	766	767	768
769	770	771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800	801	802	803	804
805	806	807	808	809	810	811	812	813	814	815	816
817	818	819	820	821	822	823	824	825	826	827	828
829	830	831	832	833	834	835	836	837	838	839	840
841	842	843	844	845	846	847	848	849	850	851	852
853	854	855	856	857	858	859	860	861	862	863	864
865	866	867	868	869	870	871	872	873	874	875	876
877	878	879	880	881	882	883	884	885	886	887	888
889	890	891	892	893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908	909	910	911	912
913	914	915	916	917	918	919	920	921	922	923	924
925	926	927	928	929	930	931	932	933	934	935	936
937	938	939	940	941	942	943	944	945	946	947	948
949	950	951	952	953	954	955	956	957	958	959	960
961	962	963	964	965	966	967	968	969	970	971	972
973	974	975	976	977	978	979	980	981	982	983	984
985	986	987	988	989	990	991	992	993	994	995	996
997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008
1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020
1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032
1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044
1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056
1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068
1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080
1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092
1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104
1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116
1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128
1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140
1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152
1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164
1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176
1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188
1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200
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1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224
1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236
1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248
1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260
1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272
1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284
1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296
1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308
1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320
1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332
1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344
1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356
1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368
1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380
1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392
1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404
1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416
1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428
1429	1										

GAGE READINGS (Continued)												
12.	1.3	6.4	2.1	8.5	8.2	2.70	3.1	0.95	0.4	0.75	0.9	1.60
13.	1.7	5.5	1.8	8.65	7.7	2.60	2.9	0.95	0.4	0.75	0.75	1.75
14.	1.6	4.9	3.0	8.75	7.1	2.5	2.9	1.05	0.4	0.9	0.7	1.6
15.	1.3	4.2	2.7	8.75	6.55	2.4	2.8	1.0	0.35	1.1	0.6	1.4
16.	1.0	2.7	1.9	8.75	6.1	2.35	2.5	0.95	0.35	1.2	0.7	1.75
17.	1.2	2.4	1.75	8.85	5.6	2.3	2.35	0.85	0.35	1.2	0.9	1.9
18.	1.0	3.1	2.4	8.90	5.3	2.5	2.25	0.7	0.35	1.3	0.9	2.0
19.	1.0	4.4	3.1	8.95	4.9	2.5	2.15	0.75	0.3	1.3	1.0	1.85
20.	0.9	6.0	4.1	8.9	4.5	2.5	2.05	0.7	0.25	1.25	-0.4	1.7
21.	0.8	4.5	4.4	9.1	4.4	2.6	1.95	0.7	0.25	1.20	-0.15	1.6
22.	0.7	4.6	4.4	9.2	4.35	2.6	1.90	0.65	0.2	1.2	0.6	1.7
23.	0.5	5.0	4.6	9.25	4.2	2.7	1.8	0.6	0.15	1.1	0.85	2.1

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GAGE READINGS (Continued)												
24.	0.95	3.5	7.0	9.25	4.2	2.7	1.75	0.55	0.15	1.05	0.7	2.75
25.	0.9	3.2	7.1	9.35	4.1	2.6	1.7	0.55	0.1	1.1	0.6	3.5
26.	0.7	3.55	6.9	9.35	4.0	2.7	1.6	0.5	0.1	1.1	0.45	3.3
27.	0.5	3.4	6.4	9.65	3.8	2.75	1.5	0.5	0.1	1.1	0.2	2.1
28.	0.45	3.7	5.8	9.9	3.6	2.9	1.4	0.5	0.1	1.05	0.2	1.55
29.	0.7		5.5	9.95	3.5	3.0	2.3	0.5	0.15	1.05	0.65	1.55
30.	0.6		5.4	10.05	3.4	3.0	1.25	0.5	0.1	1.05	2.00	1.60
31.	1.0		6.1		3.75		1.3	0.5		1.05		

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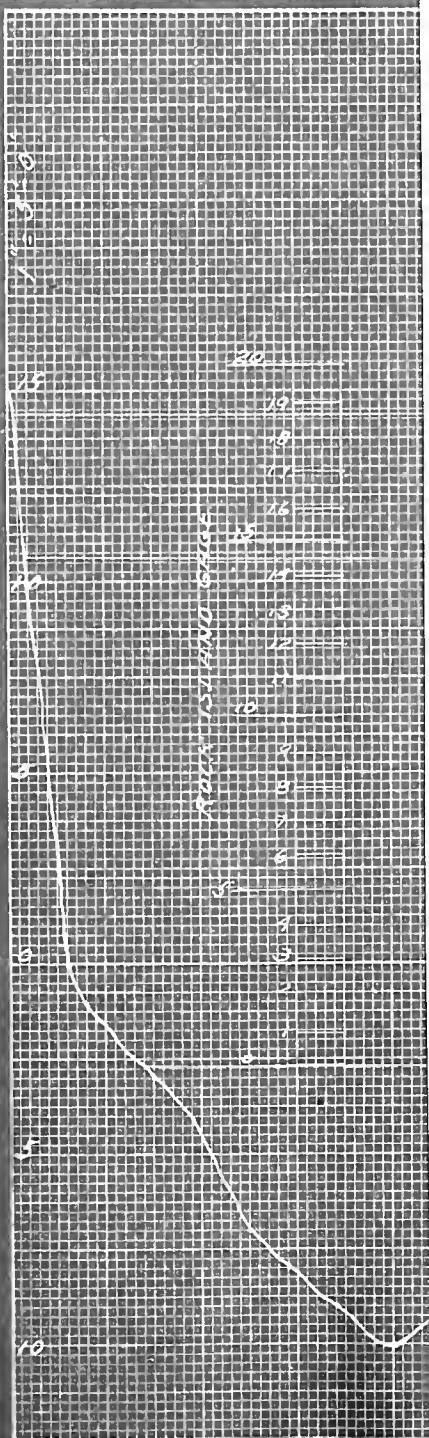
The only available data on the discharge measurements of the Mississippi River at Rock Island are given on the following table:

Location	Year.	Stage above L.W.	Width. ft.	Wetted per im- iter. ft.	Area sq. ft.	Mean veloc- ity per second ft.	Discharge per sec- ond. cu. ft.
Rock Island	1878	2.1	2,444	2,445	19,109	1,5860	30,313
do.	1880	18.4	2,737	2,740	60,880	4,3456	251,348

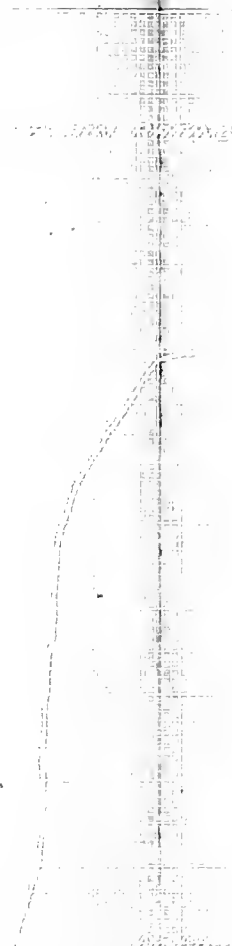
A cross-section of the river corresponding to the above data will be found on page .

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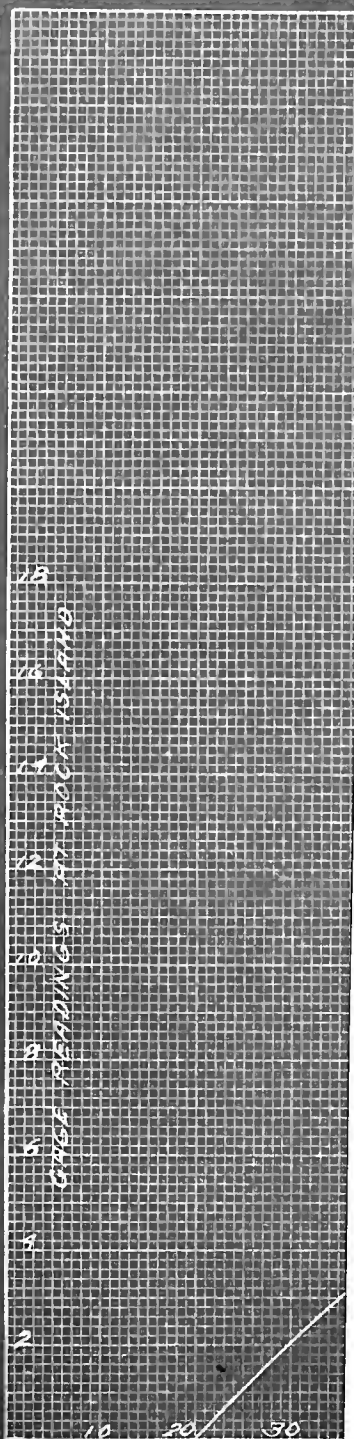
Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100																			
Population	1,000,000	1,050,000	1,100,000	1,150,000	1,200,000	1,250,000	1,300,000	1,350,000	1,400,000	1,450,000	1,500,000	1,550,000	1,600,000	1,650,000	1,700,000	1,750,000	1,800,000	1,850,000	1,900,000	1,950,000	2,000,000	2,050,000	2,100,000	2,150,000	2,200,000	2,250,000	2,300,000	2,350,000	2,400,000	2,450,000	2,500,000	2,550,000	2,600,000	2,650,000	2,700,000	2,750,000	2,800,000	2,850,000	2,900,000	2,950,000	3,000,000	3,050,000	3,100,000	3,150,000	3,200,000	3,250,000	3,300,000	3,350,000	3,400,000	3,450,000	3,500,000	3,550,000	3,600,000	3,650,000	3,700,000	3,750,000	3,800,000	3,850,000	3,900,000	3,950,000	4,000,000	4,050,000	4,100,000	4,150,000	4,200,000	4,250,000	4,300,000	4,350,000	4,400,000	4,450,000	4,500,000	4,550,000	4,600,000	4,650,000	4,700,000	4,750,000	4,800,000	4,850,000	4,900,000	4,950,000	5,000,000	5,050,000	5,100,000	5,150,000	5,200,000	5,250,000	5,300,000	5,350,000	5,400,000	5,450,000	5,500,000	5,550,000	5,600,000	5,650,000	5,700,000	5,750,000	5,800,000	5,850,000	5,900,000	5,950,000	6,000,000	6,050,000	6,100,000	6,150,000	6,200,000	6,250,000	6,300,000	6,350,000	6,400,000	6,450,000	6,500,000	6,550,000	6,600,000	6,650,000	6,700,000	6,750,000	6,800,000	6,850,000	6,900,000	6,950,000	7,000,000	7,050,000	7,100,000	7,150,000	7,200,000	7,250,000	7,300,000	7,350,000	7,400,000	7,450,000	7,500,000	7,550,000	7,600,000	7,650,000	7,700,000	7,750,000	7,800,000	7,850,000	7,900,000	7,950,000	8,000,000	8,050,000	8,100,000	8,150,000	8,200,000	8,250,000	8,300,000	8,350,000	8,400,000	8,450,000	8,500,000	8,550,000	8,600,000	8,650,000	8,700,000	8,750,000	8,800,000	8,850,000	8,900,000	8,950,000	9,000,000	9,050,000	9,100,000	9,150,000	9,200,000	9,250,000	9,300,000	9,350,000	9,400,000	9,450,000



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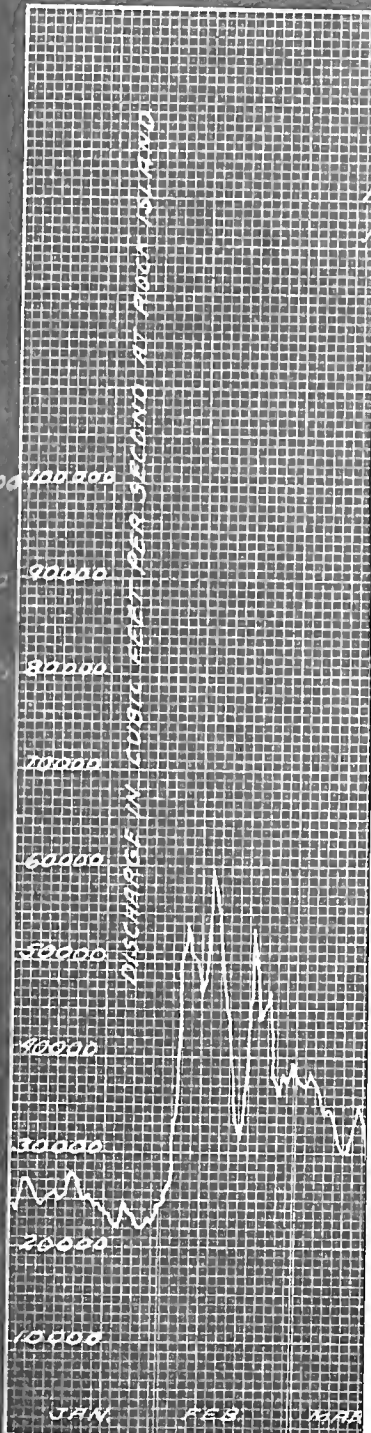
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A Longitude

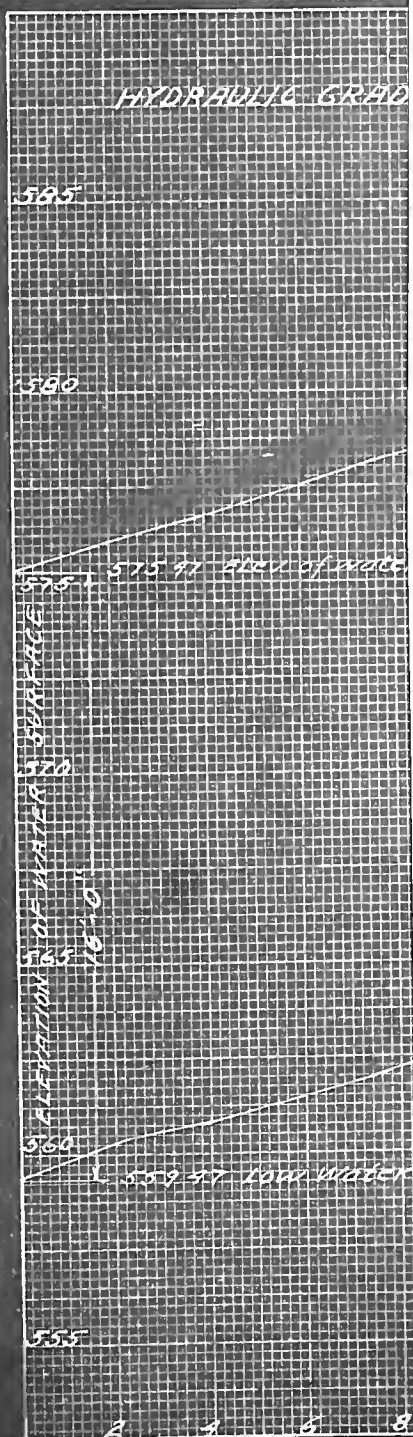




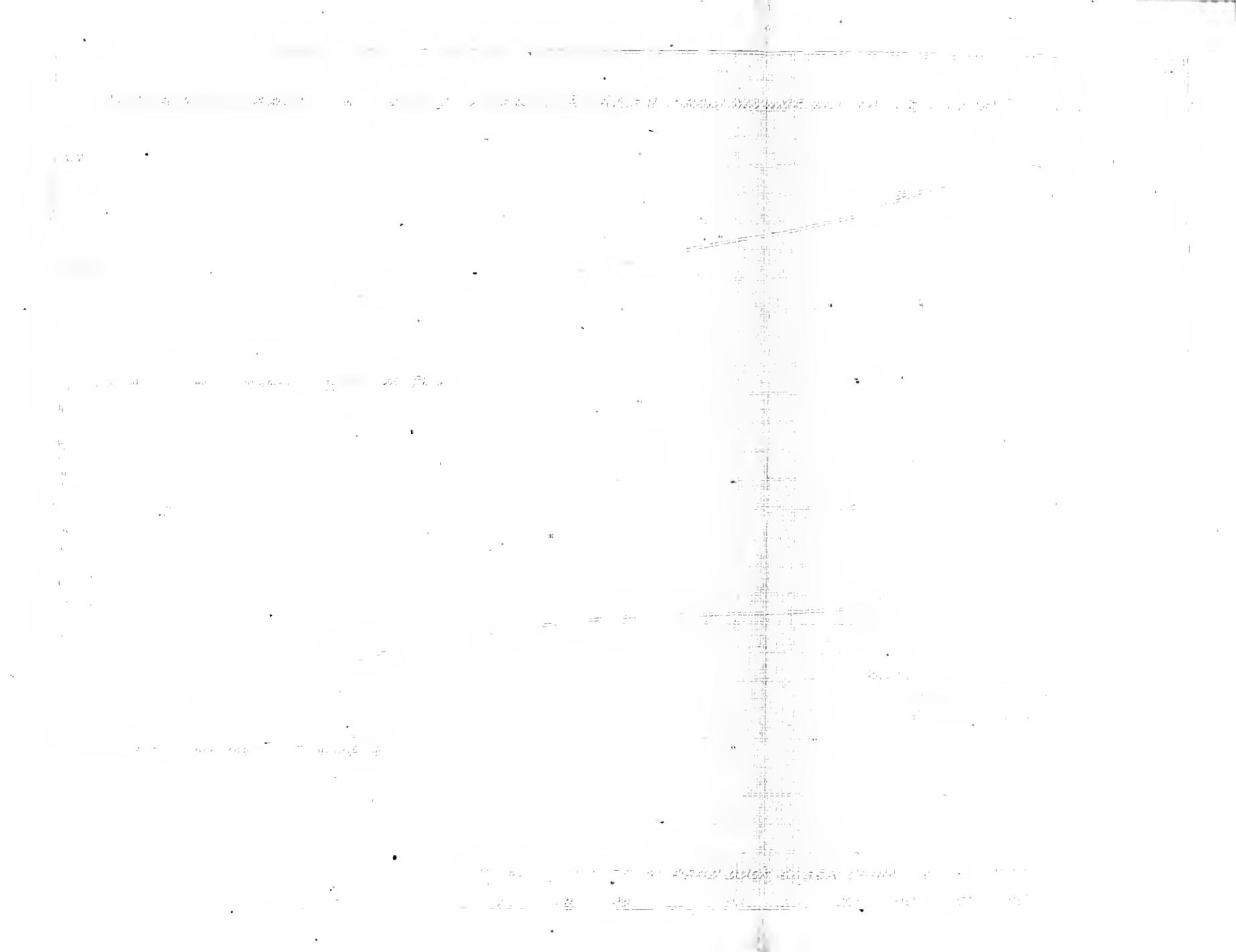




A. Longitude











A longitudinal profile of the river showing the original and new water elevations caused by the dam is shown on page 17.

#### AVAILABLE POWER.

From a careful study of the hydrograph, it was thought inadvisable to base the calculations upon the minimum flow which only lasted thru a period of two days. A flow of 30,000 cubic feet per second may be relied upon for practically fifty per cent of the time, so this value was used with the assumption that a steam reserve could be depended upon during the dry periods.

The horse power available was calculated from the formula:

$$\text{H.P.} = \frac{qhEw}{550}$$

q = quantity of water in cu. ft. per sec.

h = head in feet.

E = Efficiency taken as 80%

w = weight of a cubic foot of water.

$$\text{H.P.} = \frac{30000 \times 16 \times .80 \times 62.5}{550} = 43,700 \text{ or}$$



say 45,000.

#### DESCRIPTION OF DAM.

The main dam from the Iowa side to the power house is designed to be 4625 feet long, of which 2975 feet is spillway in the present bed of the river and the remaining 1175 feet retaining shore dam. The spillway section of the dam is to consist of 119 arch spans, each twenty-five feet between piers four feet thick and an average height of thirty feet, forming a bridge eighteen feet wide on top. An Ogee shaped overfall will occupy the lower part of the space under each arch between the piers with a steel vertical lift gate resting on its crest to control the flow.

#### DESIGN OF DAM.

The maximum flood volume to be discharged is 280,000 cubic feet per second. Assuming that there will be 119 spillway sections, each section must discharge

$$\frac{280000}{119} = 2350 \text{ cubic feet per second.}$$

The length of the crest will be calculated from the formula:



$$L = \frac{Q}{C H^{\frac{3}{2}}}$$

Using a value of "C" equal to 3.33 and solving for L we get

$$L = \frac{2350}{3.33 \times 36.3} = 19.45 \text{ feet}$$

Because of the uncertainty in using the value of "C" it was deemed advisable to make L equal twenty-five feet. This will provide for a maximum discharge of

$Q = 3.33 \times 25 \times 36.3 \times 119 = 359,000$  cubic feet. of water per second or 28.2 per cent in excess of the required amount.

Diagrams showing the stresses in the dam with the reservoir empty and full are shown on drawings No. III. Stresses in the heel and toe were calculated from the formulas:

$$P = \frac{R \sin \alpha}{L} \left( 1 \pm \frac{6e}{L} \right)$$

R = Resultant pressure on base.

L = Length of base.

e = Eccentricity.

$\alpha$  = Angle that the resultant makes with the base.



### THE POWER HOUSE.

The power house which is located on the Illinois side, is 800 feet long, 109 feet wide and 123 feet high from the lowest point in the tail race to the highest point on the roof. It will contain twenty main turbine and generator units, and two smaller units.

The superstructure is built of reinforced concrete and contains three floors. The generators and transformers are located on the main floor. The second floor carries the oil-switches and the third the high tension bus-bars and the electrolytic lightning arresters.

The floors were designed as concrete slabs supported by steel I beams which rest either on concrete piers or are attached to pilasters. Triangle mesh reinforcement was used in the second and third floors.

The substructure is built almost entirely of concrete, steel being used only in two places, at the turbine bearing, and in the wall on the intake side of the power house.





### The Intakes and Scroll Cases:

The water enters each turbine thru three intakes which unite in forming the scroll case, the intakes being made with a gradually decreasing cross-section from the entrance to the scroll case. The scroll case is moulded in the concrete around the turbine, and its cross-section also decreases uniformly, the rate of decrease being such that the same amount of water, and at the same velocity, will pass thru equal parts of the turbine circumference.

### The Draft Tubes:

After passing thru the turbine the water enters the draft tube, which is circular and twelve feet in diameter immediately below the turbine. Each draft tube is forty feet long and in the first eight feet of its length the cross-section changes from a circular to an elliptical section then being maintained up to the tail race. The area keeps steadily increasing from the wheel to the tail race, the effect being to reduce the wheel discharge of 15.2 feet



per second to 4 feet per second at the end of the draft tube, and to increase the effective pressure of water on the turbines.

#### The Turbines:

There are twenty main turbines of the vertical shaft single runner type. Each turbine will develop 2500 H.P. under a sixteen foot head. The effective diameter of the turbine wheel is nine feet and it passes 1720 cubic feet of water per second under a sixteen foot head. Eighteen of the turbines are required to develop the rated output of the plant, two being kept as spare units and for use in times of high tail-water. The speed of the turbines is 56 r.p.m. To drive the excitors two small turbines are placed at the center of the power house. They are rated at 900 H.P. each, and under a sixteen foot head pass 573 cubic feet per second. All of the turbines are made by the Morgan Smith Co. To regulate the speed Lombard oil-pressure governors are used.

#### The Generators:

The generators are three phase, 25



cycle alternators, coupled directly to the turbines. They are built by the General Electric Co. and are of the revolving field type, having a rating of 1875 kva. at 11000 volts when operating at normal speed.

To excite the fields of the alternators and to furnish light to the station, two direct current, 500 KW. 110 volt generators are installed. If required, one of these machines is capable of supplying all of the excitation current needed by the alternators.

#### Other Electrical Apparatus.

The voltage of each alternator is stepped up from 11,000 to 70,000 volts by means of three single phase transformers. The transformers are each rated at 750 kva., and have both their primary and secondary sides connected in delta. The transformers are connected to the high-tension bus-bars thru 70,000 General Electric oil-switches, type H<sub>6</sub>. The low tension sides of the transformers are connected to the alternators thru General Electric K<sub>2</sub> switches.



To protect the transmission lines and the electrical apparatus from damage due to lightning discharge, electrolytic lightning arresters, connected to the lines thru horn gaps, are installed. The horn gaps are provided with disconnecting switches to disconnect the arrester from the line whenever it is required to do so.

#### Roof Trusses:

The steel roof trusses, which are spaced ten feet apart and span over the entire width of the building, were designed and built by the Chicago Bridge Co. They support the roof which is covered with green tiles.

#### Crane:

To provide for the handling of the generators and turbines, a thirty ton crane, placed forty-three feet above the generator floor, is used, the power required to operate it being taken from the direct current buses.





## DESIGN OF DAM.

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### Details of Design.

#### General Data:

The low water mark was taken at Elev. 560.34. By raising the water level sixteen feet at the dam the water surface will be at Elev. 576.34. The dam is so designed that the water surface will always be at the same level whether the river is discharging its maximum or minimum amount of water. Although the highest water level ever expected will only reach elevation 576.34, it was thought advisable to take 578.34 as a basis for the design. The top of the steel vertical lift-gates will be at Elev. 580.0.

These gates are to slide in vertical grooves in the concrete piers and are to be lifted and operated by a traveler of the wrecking-crane type, running on tracks upon the bridge.

#### Method of Design:

The dam will be designed in two separate sections as was done in the Keokuk project.



The pier will be assumed to take the dead load due to the weight of the arch bridge, the steel lift-gate when it is raised from the crest of the spillway, and the weight of the pier itself. It must also take any lateral pressure that the water may exert on the gates.

The overfall or spillway section, is so designed that the area of the base is sufficiently large to take care of the entire shearing force due to the lateral pressure of the water, without transmitting any of it to the piers.

The dam will be investigated when the pond is empty and when it is full for the following conditions:-

Maximum stresses at the toe and heel.

Stability against overturning.

Shearing force on the base.

Design of the Piers: Reservoir empty.

For the preliminary design the piers were assumed to be four feet thick. The top of the bridge was made 6.66 feet above the high water mark making the elevation 585.0 or 33.5



feet above the river bed. Assuming the concrete to weigh 150 pounds per cubic foot, the weight of the pier is:

$$\frac{18 + 36}{2} \times 33.5 \times 4 \times 150 = 542,000 \text{ lbs.}$$

and the weight of the bridge

$$\frac{2 + 4}{2} \times 18 \times 19 \times 150 = 10,600 \text{ lbs.}$$

making a total of 552,600 lbs.

By taking moments about the heel of the dam the resultant force was found to act at a distance of 13.9 feet from the heel, giving an eccentricity of 4.1 feet. Using the formula given on page 8 the maximum stress in the heel and toe were found to be:

$$P = \frac{552600}{36 \times 4} \left( 1 + \frac{6 \times 4.1}{36} \right) = 6512^{\#} \text{ per sq.ft.}$$

$$P = \frac{552600}{36 \times 4} \left( 1 - \frac{6 \times 4.1}{36} \right) = 2680^{\#} \text{ per sq.ft.}$$

Design of Pier:      Reservoir full.

The stresses in the abutment were next



calculated by assuming the level of the water in the pond to be at Elev. 578.34 and with the lift-gate resting on the crest of the spillway.

As before, the total dead load will be 552,600 lbs. acting at a distance of 13.9 feet from the heel of the dam.

The horizontal pressure on the gate due to the water was found to be:

$$\frac{687.5}{2} \times 11 \times 25 = 94,500 \text{ \#}$$

By combining these two forces graphically, the resultant pressure was found to be 560,000 lbs. with an eccentricity of three inches. The eccentricity in this case is so small that the pressure may be considered as being uniformly distributed over the base, making the pressure per square foot equal to

$$\frac{552,600}{36 \times 4} = 3870 \text{ \#}$$

#### Safety Against Overturning:

The only force tending to overturn the





dam will be the horizontal water pressure, and the force tending to hold it down is the weight of the part considered. These two forces acting at right angles to each other form couples upon which the stability of the structure is dependent.

The dam will tend to overturn about the toe, which is therefore taken as the center of moments. The overturning force is

$$94,500 \times 19 = 179,600 \text{ Ft. Lbs.}$$

The resisting force is

$$552,680 \times 22.1 = 12,180,00 \text{ Ft. Lbs.}$$

Factor of safety against overturning

$$\frac{12,180,000}{179,600} = 67.8$$

Shearing on the Base:

To prevent the dam from moving bodily down stream the entire base was embedded four feet below the river bed which is of blue limestone and able to withstand a bearing pressure



of thirty tons per square foot.

The force tending to shear off the base is the horizontal water pressure. This shearing force is resisted by the area of the pier at the base. The unit shearing force is then:

$$\frac{94500}{36 \times 4 \times 144} = 4.56 \text{ \# per sq. in.}$$

#### Design of Spillway, Pond Empty:

In determining the shape of the overfall it was decided to make the spillway conform as nearly as possible to the shape of a parabola. The equation of the parabola selected was

$$y = \sqrt{10x}$$

This equation did not give quite the form desired, but by broadening out the curve a little the desired results were obtained.

For the preliminary design the width of the base was taken as 29 feet and the height above the river bed as 15.5 feet. Considering a section one foot wide, the weight is approximately 46,000 lbs. acting at a distance of ten



feet from the heel of the dam. The steel gate was assumed to weigh 2000 lbs. making a total weight of 48,000 lbs.

With an eccentricity of 4.5 feet the pressure at the heel and toe were found to be

$$P = \frac{48,000}{29} \left( 1 + \frac{6 \times 4.5}{29} \right) = 3200\# \text{ per sq.ft.}$$

$$P = \frac{48,000}{29} \left( 1 - \frac{6 \times 4.5}{29} \right) = 150\# \text{ per sq.ft.}$$

#### Design of Spillway, Pond Full:

The dead load will be the same as before, 48,000 lbs. In addition to this we have for the vertical weight 2000# additional, due to the water on the crest, thus making a total of 50,000 lbs.

The horizontal water pressure is

$$\frac{62.5(33.5 - 15.42) 15.42}{2} = 15,600\#$$

Combining the above forces graphically, the resultant pressure was found to be 52,000 # with an eccentricity of eleven inches,



thus making the pressure at the heel and toe

$$P = \frac{50,000}{29} \left( 1 + \frac{6 \times .833}{29} \right) = 3000\# \text{ per sq.ft.}$$

$$P = \frac{50,000}{29} \left( 1 - \frac{6 \times .833}{29} \right) = 1452\# \text{ per sq.ft.}$$

Shear on Base:

The area to resist the shear is  $29 \times 1 = 29$  sq. ft. making the shear per sq. in.

$$\frac{15600}{29 \times 144} = 3.73 \#$$

Stability :

The overturning moment is

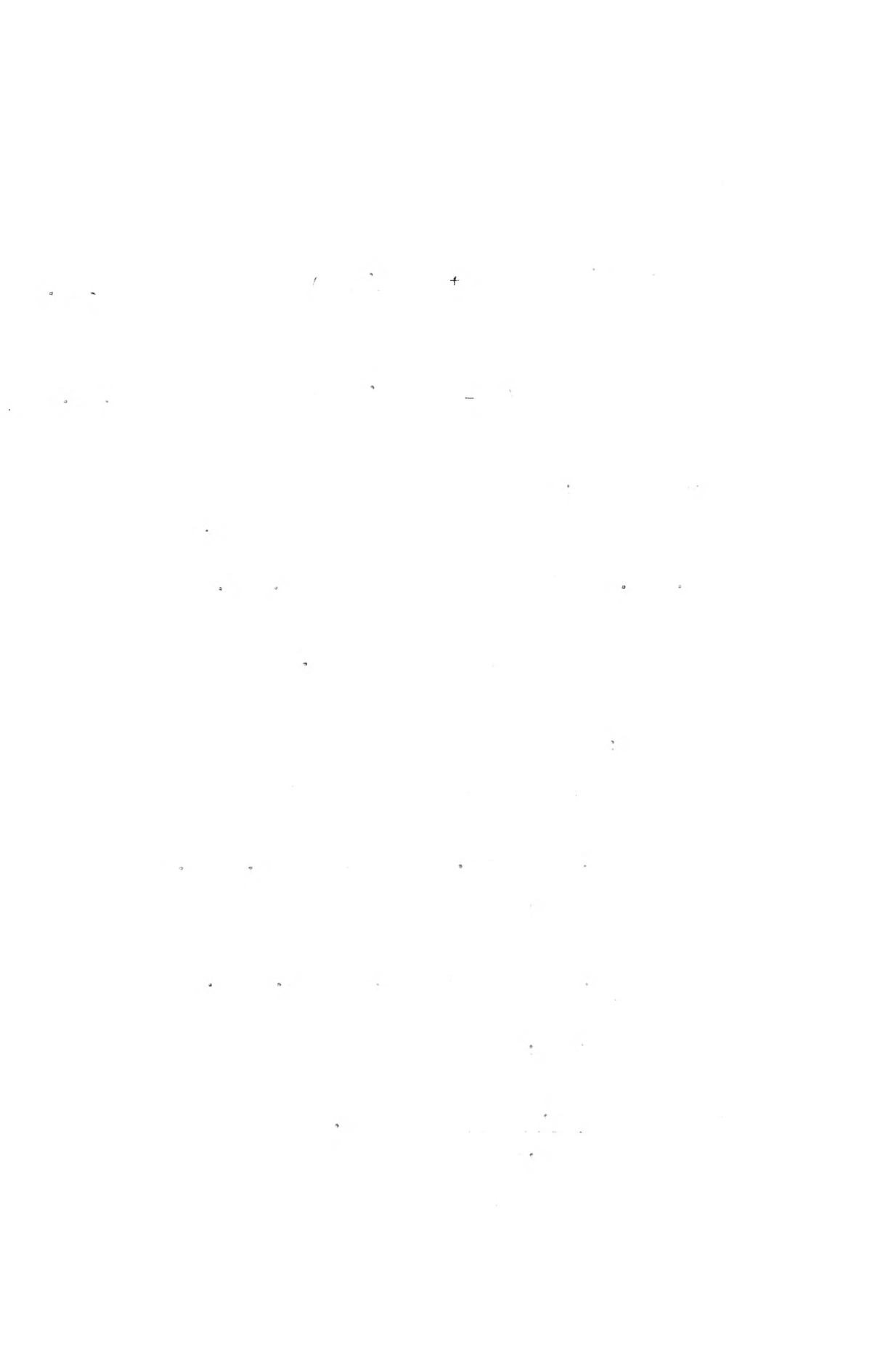
$$15,600 \times 10.6 = 165,500 \text{ Ft. Lbs.}$$

Resisting Moment:

$$50,000 \times 19 = 950,000 \text{ Ft. Lbs.}$$

Factor of Safety:

$$\frac{950,000}{165,500} = 5.26$$





## THE POWER HOUSE.

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### Detail Design.

#### Gallery Floor:

The gallery floor is designed to carry the lightning arresters, the high tension bus-bar compartments and the line compartments.

I beams support this floor every four feet in order to carry the load on this floor to the wall and to the posts. This floor, and the two floors below it, are 28 ft. 6 in. wide. The weight of each lightning arrester is 2750#, of the bus bar compartment 5912# and of the line compartment 10,800#.

These loads give a maximum bending moment of 662,400 in. lbs., and for a working stress of 16,000 lbs. per sq. in. in the steel I beam whose section modulus is

$$\frac{662,400}{16,000} = 42, \text{ needed.}$$

12 in. 40 lb. I beams have the requir-



ed section modulus and are used. They carry the 3.5 in floor slab on which the compartments and lightning arresters are placed.

As there is no wall to fasten these I beams to on the side nearest the generator room, they are fastened to other I beams, 20 ft. in length running lengthwise of the building between steel posts. The posts are 20 ft. apart and the I beams between them must support the load of four of the 12 in. 40 lbs. I beams.

The section modulus found for the 20 ft. I beams was 207, which gave 24"-105# I beams for the girders between posts.

#### Balcony Floor :

This floor is designed to carry the weight of the oil switches and line compartments. A concrete slab 4.5" thick was used, and I beams were placed under it every 4 feet, as in the floor above.

The weight from the oil switch which goes to one I beam was 11,340#, and the weight of the compartment 9180#. 18"-70# I beams are



needed for this floor between the wall and girders, the girders being 20"-85# I beams.

#### Transformer Floor:

On account of the depression in the floor for the tracks running along the building, the beams in the floor were not placed as in the other two floors, but lengthwise. This was done to avoid an excessive use of concrete for the floor slab.

The transformers weigh 12,935# each, and are placed 10 ft. apart. The area of the bottom of each transformer is 13.75 sq. ft., which gives 942.5 # per sq. ft. of floor. The bending moment due to this load is

$$\frac{1}{8} w l^2 = \frac{942.5 \times 3 \times 3 \times 12}{8} = 12,720 \text{ in.lbs.}$$

the beams which are to support the concrete slab being three feet apart.

The thickness of concrete required is

$$d = \sqrt{\frac{M}{R b}} = \frac{12720}{110 \times 12} = 9.65 \text{ in.}$$



The slab was made 10" thick and weighs 120# per sq. Ft.

Each beam supports a three foot width of slab = 360 # per ft.

$$\text{B.M.} = \frac{1}{8} w l^2 = \frac{360 \times 20 \times 20 \times 12}{8} = 130,000 \text{ in.lbs.}$$

When the transformers are moved, each beam will have to take half the weight of one transformer, and this must be considered.

This gives a bending moment of 388,000 in. lbs. which must be added to the 130,000 previously found. The I beams required to resist the total bending moment are 12"-31.5#

These are supported every ten feet by beams af, de, bg, etc., each of which carries the load of one transformer in one panel as afde. The members required for this load are 24"-80# I beams.

The beams between the 20 ft. posts, as de, must be carried on girders ab, bc, etc., ab carries one half the load from de, and the beams required are 18"-65# I beams.





### Design of Racks:

The size of openings in the racks was made so that velocity of the water thru the racks was about 1.5 ft. per second. This would make each opening

$$\frac{1720}{1.5} = 1150 \text{ sq. ft.}$$

1720 cubic feet per second being the discharge of each turbine.

The racks were made thirty feet wide and forty feet long, the vertical height being thirty-eight feet. They consist of narrow bars of iron  $\frac{1}{4}$ " x 3", spaced 2" apart resting on horizontal I beams spaced 5' apart, which in turn are supported by two heavy I beams at the sides of the opening. These two I beams, running parallel to the racks, must be designed to withstand the full head of water in case the racks should be choked up with leaves or other materials.

The total pressure which each beam would have to take is:



$$\frac{38}{2} \times 15 \times 40 \times 62.5 = 710,000 \text{ ft. lbs.}$$

This pressure acts at a distance of  $\frac{38}{2}$  feet from the bottom, but was taken as uniformly distributed in order to simplify the calculations:

$$M = \frac{Wl^2}{8} = \frac{710,000 \times 12}{8} = 1,065,000 \text{ in.lbs.}$$

$$\frac{I}{C} = \frac{1,065,000}{16,000} = 73, \text{ which corresponds}$$

to the section modulus of a 15"-60# I beam.

The clear opening thru the racks is

$$38 \times \frac{7}{8} \times 30 = 1000 \text{ sq. ft.}$$

which gives a velocity of 1.72 ft. per second thru the racks.



# GENERAL ESTIMATE OF COST.

The figures as given below are only approximate and were obtained by comparison with the costs of existing plants and other installations of which the actual costs were known.

The Electrical World of 1910 gives the cost of the generators as \$11.00 per Horse Power generated. Since the turbines deliver 450,000 Horse Power at the turbine shaft the cost of the generators will be

$$450,000 \times \$11.00 = \$495,000.$$

Gillette's hand book of cost data gives the cost of an 800 KW. step-up transformer as \$7500. Taking this as a basis, the cost per KW. would be

$$\frac{7500}{800} = \$9.48$$

Assuming that the generators have an efficiency of 95%, the total power to be transformed is:



$$450,000 \times .95 = 42,750 \text{ K.W.}$$

making the cost of the transformers,

$$42,750 \times 9.48 = \$406,000.$$

The cost of the exciter units was taken from data given by H.M. Hobart in the Standard Handbook, who gives the cost of a 1000 K.W. direct current generator as \$10,500.

The oil switches of which there are twenty for generators and six for the out-going lines, may be obtained from the General Electric Co. at a cost of \$1200. per switch, making the total cost

$$26 \times 1200. = \$33,200.$$

The lightning arresters may be also obtained from the same company at a cost of \$1400. There will be six of these making the cost

$$1400 \times 6 = \$8400.$$

Data for the cost of the dam and power house was taken from Gillette's Handbook of Cost Data, in which the cost of a similar dam was giv-

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en as \$5.92 per cu. yd. which includes the cost of labor, concrete and form work.

The dam project will contain 61,500 cubic yards, making the cost

$$61,500 \times \$5.92 = \$363,000.$$

The power house will contain 46,400 cubic yards, making the cost

$$46,400 \times \$5.92 = \$274,000.$$

There will be a total of 85 miles of transmission line at approximately \$5000. per mile making

$$5000 \times 85 = \$425,000.$$

Switch board and station wiring will cost  $9/40$  of the generator and transformer cost or

$$9/40 \times 911,000 = \$205,000.$$

The water wheels will have a cost of approximately  $36.65/40$  of the generator and transformers making

$$\frac{36.65}{40} \times 911000 = \$752,000.$$

Allowing 10% for engineers charges and



10% for contingency charges, the total cost would be approximately \$3,600,000.



## TRANSMISSION LINE.

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## Design of Peoria Line.

20,000 KW. are to be transmitted along this line to Peoria, Ill., a distance of seventy-five miles. Two circuits will be used, each of which will normally carry one half of the power. The voltage at the receiver is 65000 volts, which gives a voltage from line to neutral of 37,800 volts.

The assumed loss at full load, with all wires in use is 15%, which gives

$$\frac{20,000 \times 15}{600} = 500 \text{ KW. as the I R loss in one}$$

line.

The current per wire is :

$$\frac{10,000 \times 1000}{3 \times 65,000} = 89 \text{ amperes .}$$

The resistance per wire is :

$$\frac{500,000}{89 \times 89} = 62.4 \text{ ohms, or .16 ohms per 1000 ft.}$$



#2 solid copper wire, having a resistance of #1594 ohms per 1000 ft. was used. This gives an actual loss of

$$89 \times 89 \times .1594 \times 5.28 \times 75 = 500,000 \text{ watts per line.}$$

The towers are placed 600 feet apart, and the distance between the wires, which are placed at the corners of triangles, is nine feet.

The inductance of each wire is:

$$.1404 \log \frac{\delta}{r} + .01524 \text{ millihenries} = .1404$$

$$\log \frac{9 \times 12}{.129} + .01524 = .425 \text{ millihenries}$$

per 1000 ft.

The capacity to neutral is:

$$\frac{38.8 \times 10}{\log \frac{2D}{d}} = \frac{38.8 \times 10}{\log \frac{18 \times 12}{.258}} = 13.3 \times 10 \text{ farads}$$

per mile.

The inductance per wire is:

$$.425 \times 75 \times 5.28 = .167 \text{ henries} = L$$





The inductive reactance is:

$$2 fL = 2 \times 25 \times .167 = 26.5 \text{ ohms per wire.}$$

The condensive reactance is

$$\frac{1}{2\pi fc} = \frac{1}{2 \times 25 \times 13.3 \times 10^3 \times 75} = 6360 \text{ ohms.}$$

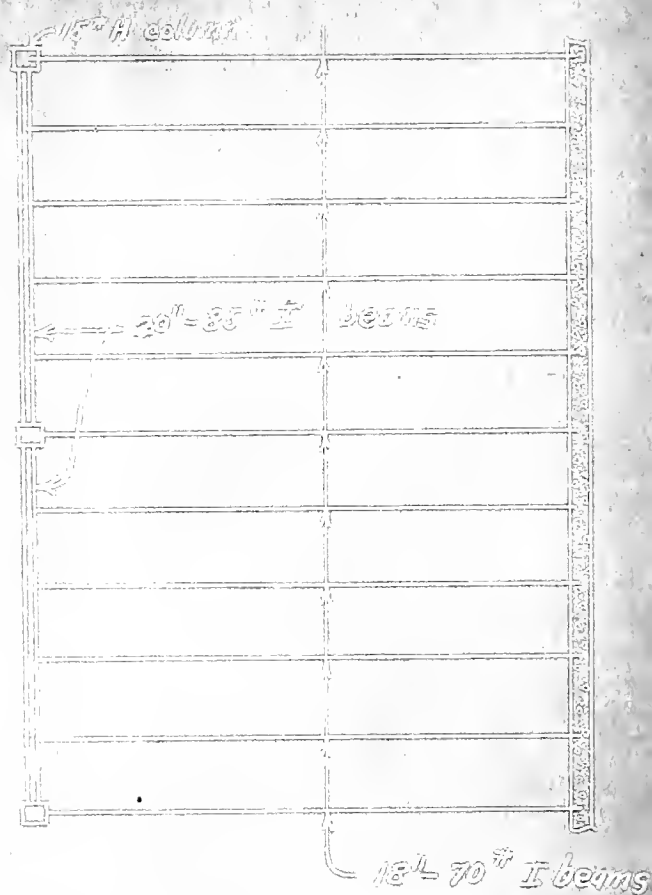
By constructing the regulation diagram the above values give 16 % for regulation at full non-inductive load and 15.8% for regulation for full load current 80% lagging power factor.



PLAN OF GALLERY FLOOR



PLAN OF BALCONY FLOOR



PLAN OF TRANSFORMER FLOOR



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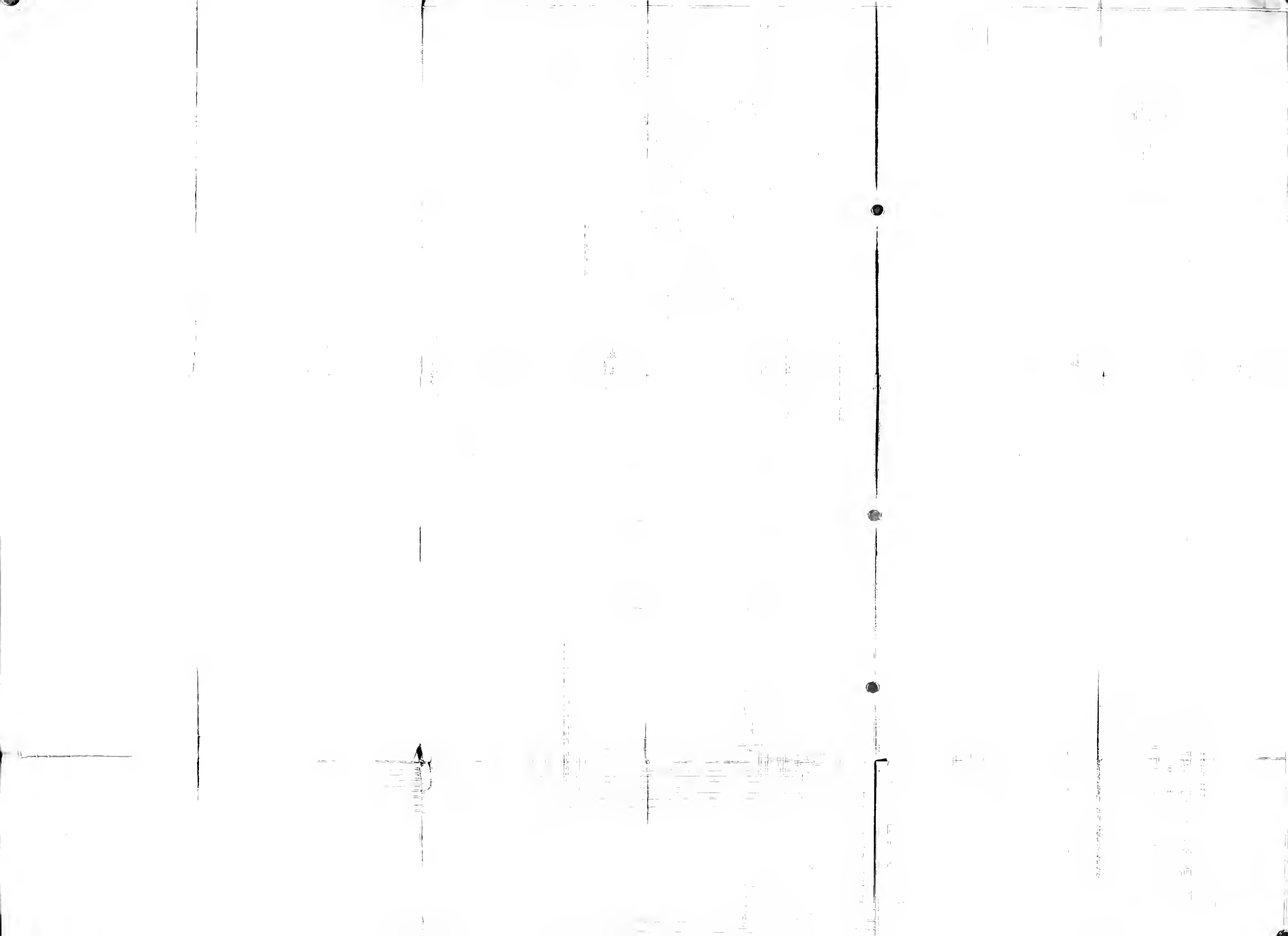


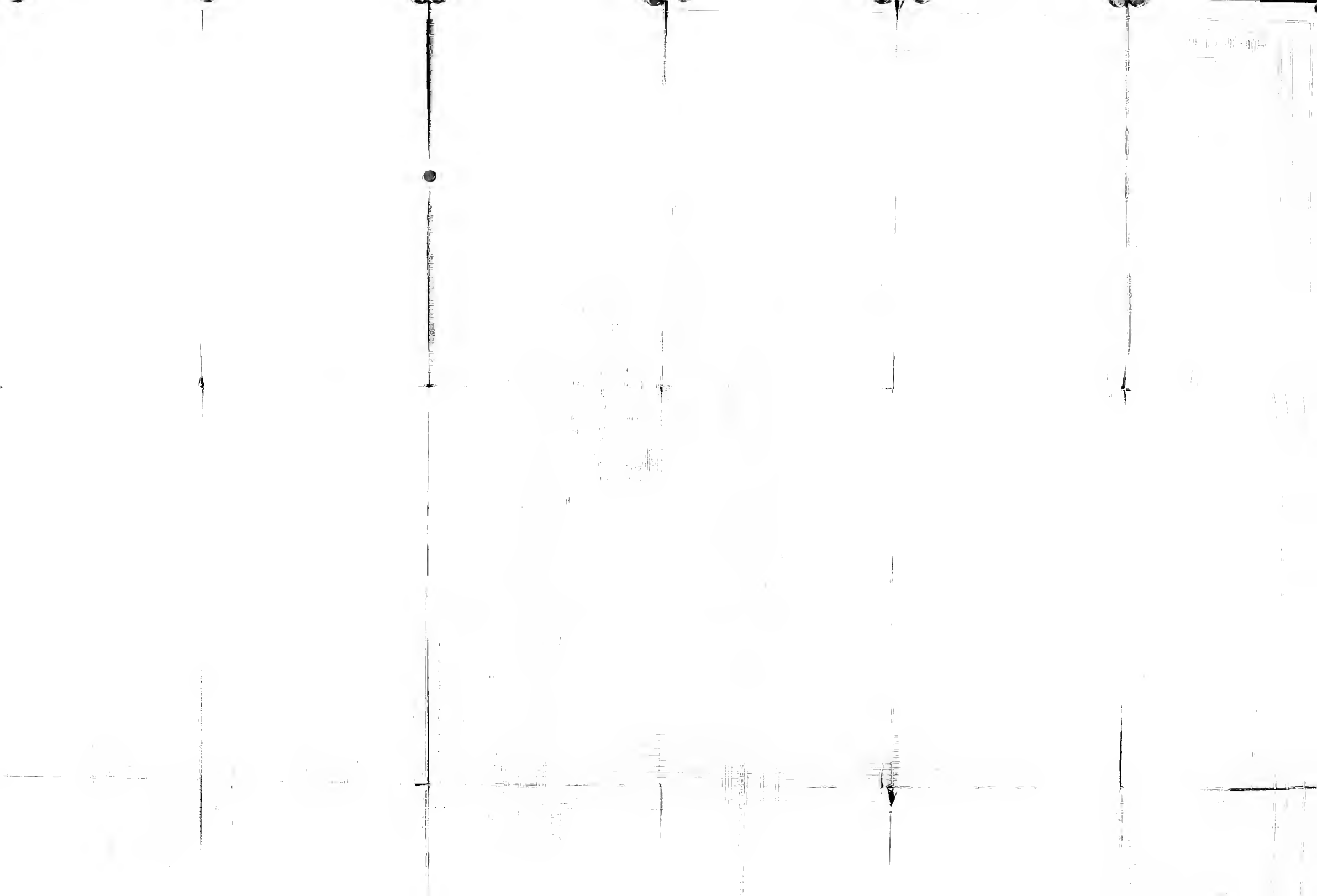


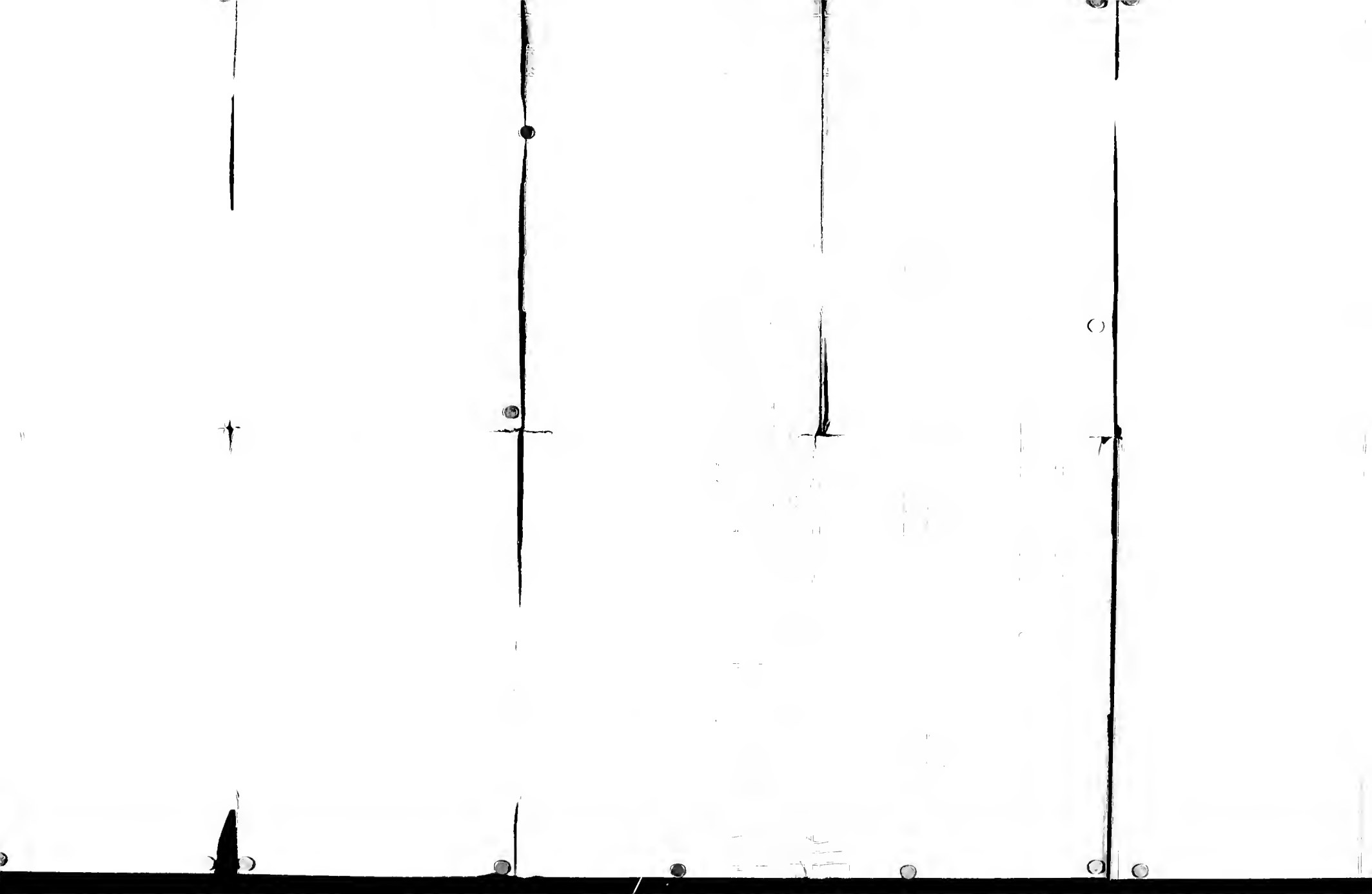




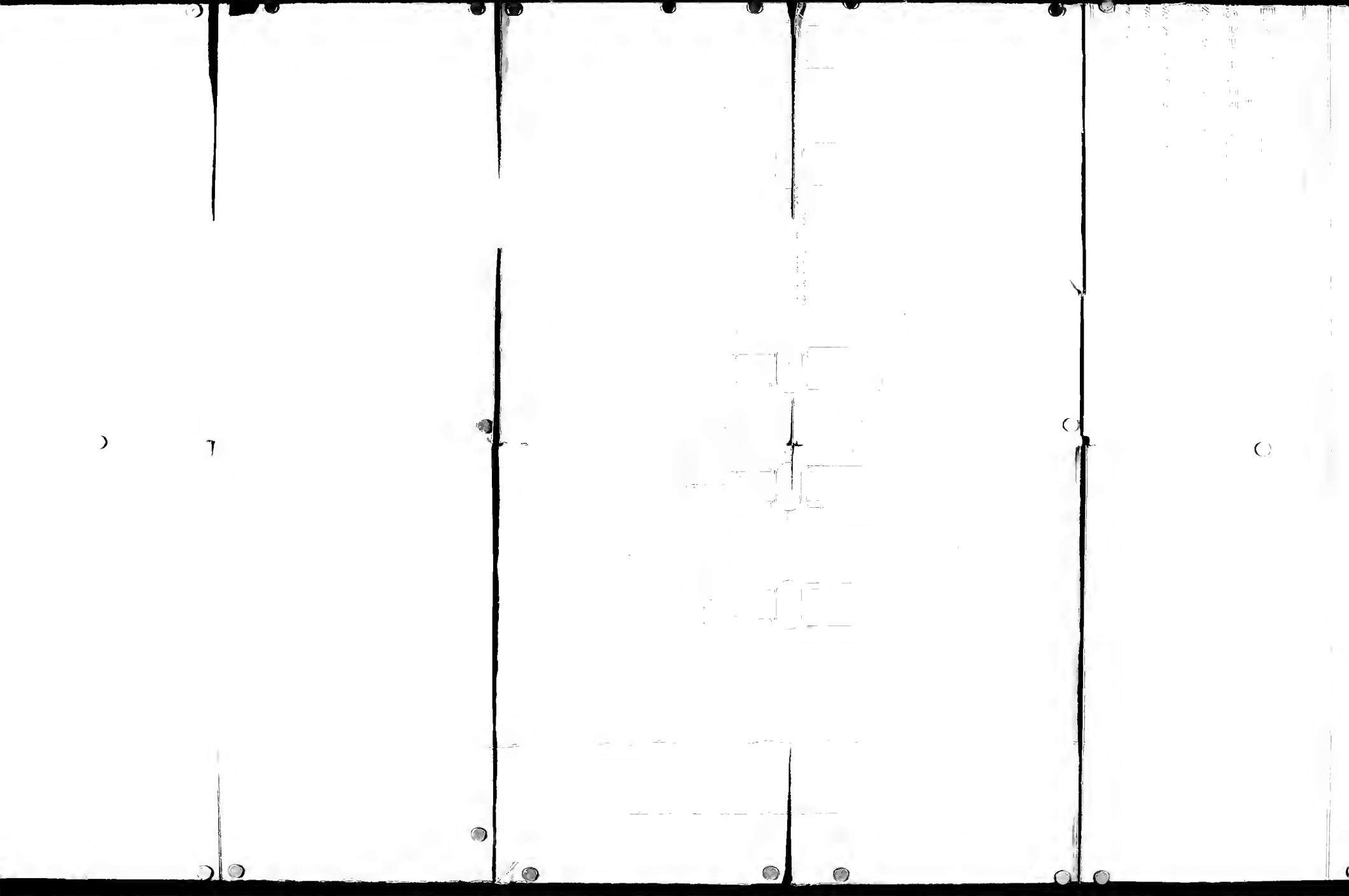


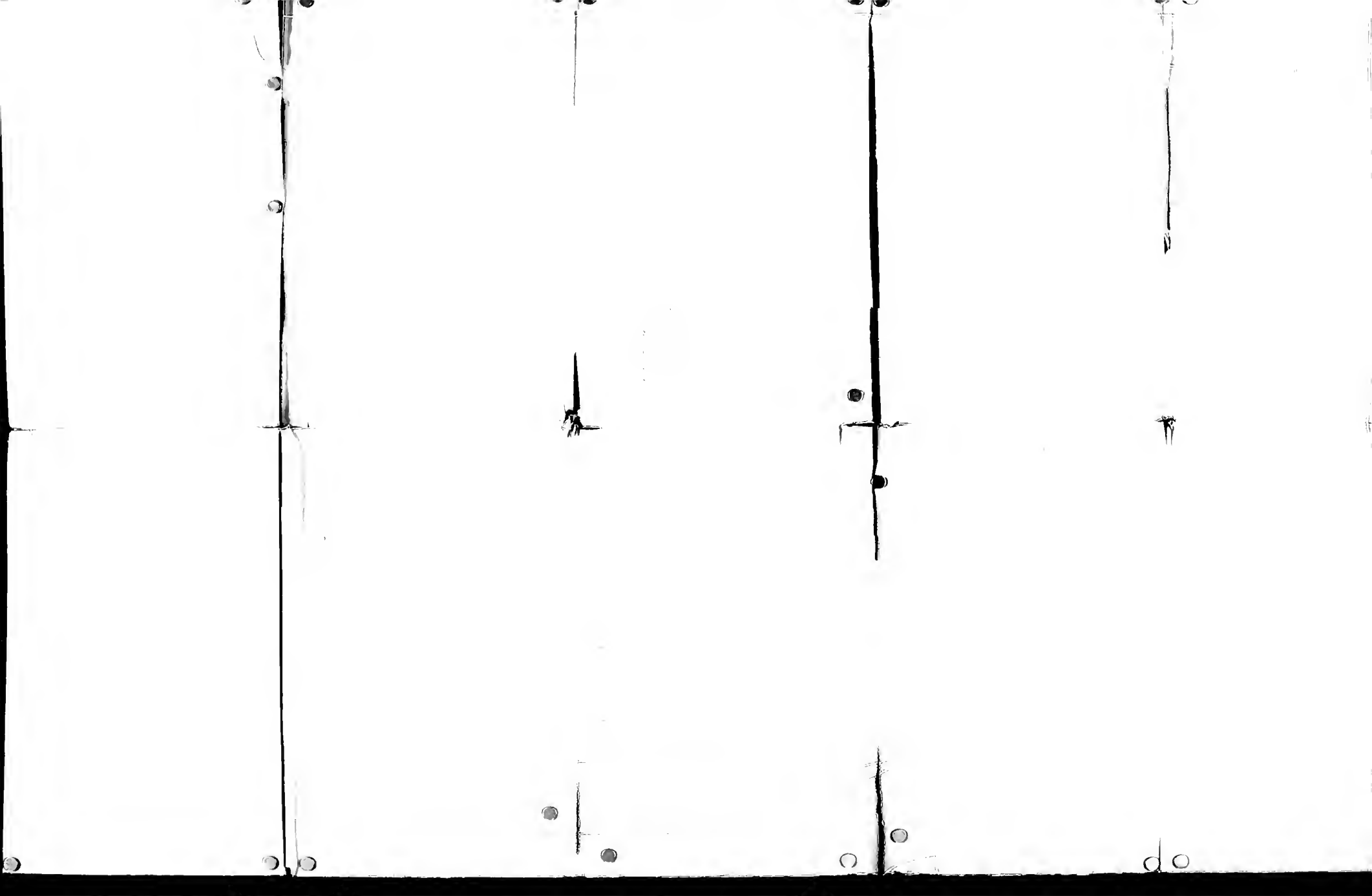


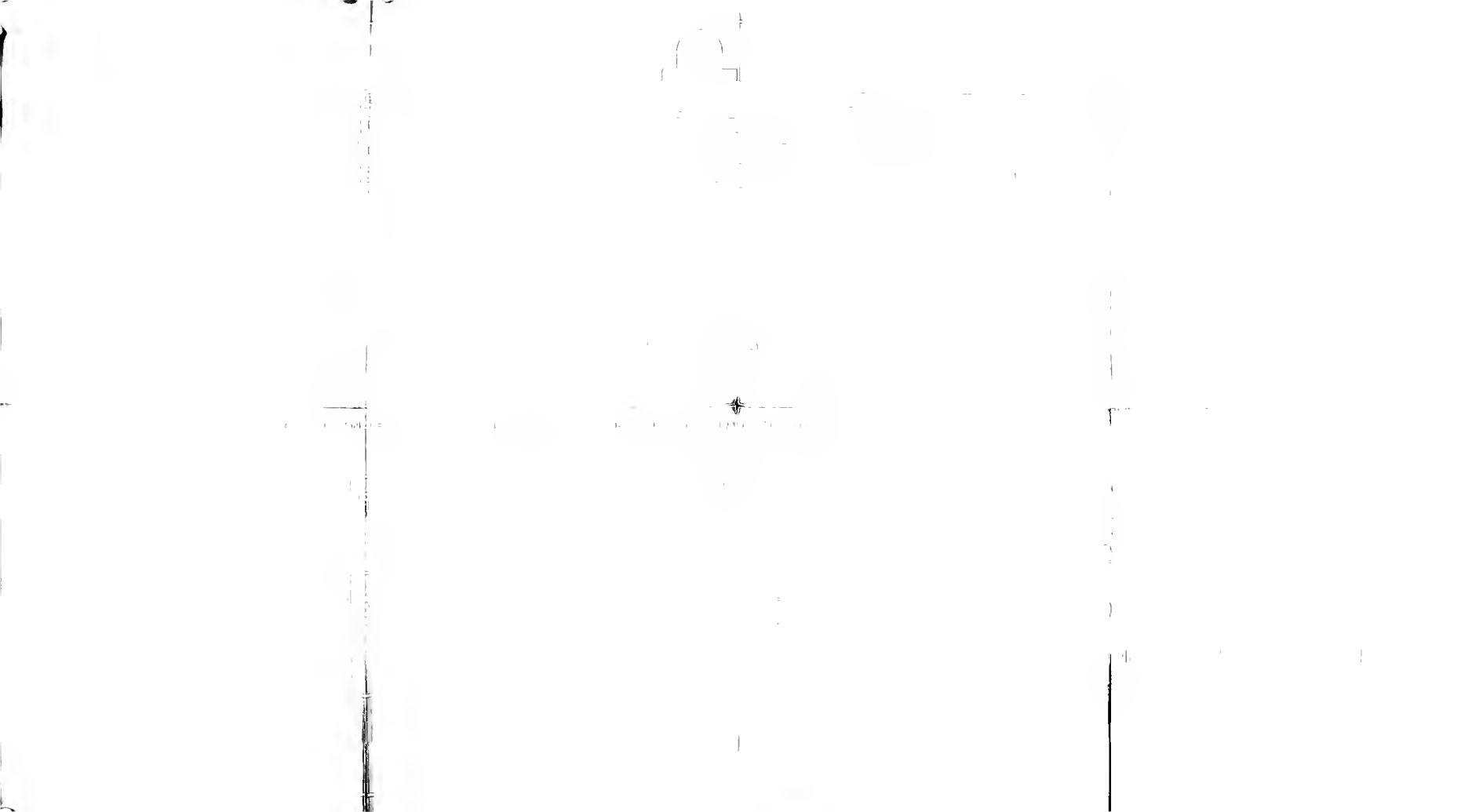


















SHEET 01

# THE MISSISSIPPI RIVER

MISSISSIPPI RIVER COMMISSION  
CHART NO. 251

INDEX CHART

